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THE CURVE OF FORGETTING

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ARCHIVES OF PSYCHOLOGY
EDITED BY
R. S. WOODWORTH

No. 21, March, 1912

COLUMBIA CONTRIBUTIONS TO PHILOSOPHY AND PSYCHOLOGY,
VOL. XX, NO. 3

NEW YORK
THE SCIENCE PRESS

Psych
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no. 21

PRESS OF
THE NEW ERA PRINTING COMPANY
LANCASTER PA

6 Feb. 1952

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THE CURVE OF FORGETTING

CHAPTER I

Historical Survey

The problems that present themselves in connection with the topic of forgetting are (1) the rate at which forgetting progresses, (2) the form of the curve showing the relation of forgetting to the lapse of time, and (3) whether there are any constant relations between either the rate of forgetting or the shape of this curve, on the one hand, and, on the other, the kinds of subject matter or the kinds f reagents, or the amount or manner of the practise or learning.

The first application of modern scientific methods in the study of nemory and of forgetting was the work of Ebbinghaus, which he published in 1885.[1] Ebbinghaus assumed that when experience has weakened in its susceptibility to recall the remaining association strength can be measured best by the number of repetitions that it saves in relearning. Another person served him as subject in preliminary experiments; but in the principal experiments Ebbinghaus acted both as experimenter and subject. As he admits, his results are, therefore, of much less value especially for general psychology. The material learned in the experiments in forgetting consisted of 163 series, each containing 13 nonsense syllables. Every syllable contained a consonant, a vowel and then another consonant. Ebbinghaus took especial pains to avoid any succession of letters or of syllables that might suggest devices in learning. He read a series and then recalled as many syllables as possible until he reproduced the whole series once without an error. Whenever a series could not be promptly recalled in its entirety he read the remainder from the paper. The rate was kept constant at 150 syllables per minute by means of a metronome. Seven of the series were memorized one day and one was relearned at each of seven intervals of various lengths. The data of the shorter periods were the average results of from 12 to 16 series, and those of the larger intervals of from 22 to 26 series.

The results of this investigation of Ebbinghaus I present in the form of a table of arrays and a table of central tendencies and meas-

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[1] "Uber das Gedächtniss," Leipzig, 1885.

TABLE I

RESULTS OF EBBINGHAUS

The Arrays of the Per Cents. Retained

Per Cent.	20 Minutes	1 Hour	9 Hours	1 Day	2 Days	9 Days	31 Days
60	5						
55	5						
50	1	4					
45	0	5	1	3	1		
40	1	3	1	2	3	1	1
35		3	6	9	1	3	2
30		1	2	4	7	6	7
25			2	3	4	3	6
20				2	3	7	8
15				2	4	3	9
10				1	2	0	6
5					1	2	6
0–5						1	
Average Deviations	4.3	5.1	4.3	7.2	9.0	10.4	7.9
Probable Errors ..	2.1	4.2	0.8	3.7	7.6	7.9	7.0
Averages	58.2	44.2	35.2	33.7	27.8	25.4	21.1
Modes	55–60	45	35	35–	30–	20–30	15

ures of variability. It can be seen that the portions of the work that were necessary to be performed again were approximately, after 20 minutes 1/3, after 1 hour 1/2, after 9 hours 2/3—, after 24 hours 2/3 +, after 6 days 3/4, and after 31 days 4/5. His statement of his conclusions from these results is, "The ratio of what is retained to what is forgotten varies inversely as the logarithm of the time."

Besides being the first experimental research in this group of phenomena, this was the first very extended laboratory investigation of the mental processes that are not closely paralleled by definite, commensurate, physical stimuli. In addition to this, all who have carried on experimental investigations in memory, and most especially in forgetting, will agree that the task as it was performed by Ebbinghaus required closeness of application and patient persistence that was nothing less than heroic. However, the fact that his work has more than one claim to a place among pioneer achievements is sufficient excuse for several imperfections in his methods.

There is good reason for believing that his work might have been more valuable for general psychology had he, with equal diligence, experimented upon several other persons. This most usual criticism of his method is atoned for in a measure by the fact that one could scarcely have been as severely exacting in his methodological requirements in that case as Ebbinghaus was with himself. Besides, learning depends so largely upon attention that any one to whom the problem was not of primary interest could not be so constant in conditions for reaction as the one to whom the research was all-important. The aim of Ebbinghaus was merely to break the ground, thus to disclose only the predominant, and therefore the most common, factors in learning and in forgetting. Of course, there was a greater possibility of mistaking some individual factors for general phenomena than there would have been in case of a number of subjects. There is indeed no assurance that the regularity in this curve was in no degree due to his knowledge of the problem and of the results to be obtained. Therefore, although there were some advantages in experimenting upon himself, there is ample reason for believing that there is considerable justness in the criticism. The subject matter that Ebbinghaus supposed to be as simple as any that could be found was probably not so simple in possibilities for association or so single in forms of imagery as material that has been chosen by several other investigators more recently.

In reading the syllables from a paper he did not avoid the possibility of dwelling longer upon the syllabes difficult to remember than upon others, and of unwittingly glancing back in review of refractory association links. This objection is stronger nevertheless in connection with his experiments for the analysis of memorizing than with reference to studies of forgetting, because more time spent upon the less associable members of the series equalizes among all members the degrees of permanence. This quality is indeed the primary desideratum in units of measure. However, it is more satisfactory to first make the members as equal as possible, and then thoroughly to control the manner and the time of their exposure. Although, according to the results of Ebbinghaus more than one third of the forgetting of nonsense syllabes takes place during the first twenty minutes, more than one half in one hour, nearly two thirds in nine hours, and more than two thirds within twenty-four hours, only one third of his data constitutes the evidence for these four out of the seven intervals. The slow loss between nine hours and one day in comparison with that preceding and following this interval is one of the doubtful results that might have been determined with a greater degree of certainty and with small sacrifice, if the experiments had been better distributed.

We are able to improve upon the methods of Ebbinghaus, not because of the lack of value of his research; but owing to the fact that his studies have supplied a general method of investigation, and thus aroused an interest in this group of phenomena that has resulted in a fruitful series of researches, and a better understanding of the problems and difficulties to be met in this field of investigation.

While the first part of the investigation that is reported later in

TABLE II

RADOSSAWLJEWITSCH'S RESULTS

	Adults		Children	
Time	Without Meaning Per Cent. of Forgetting	With Meaning Per Cent. of Forgetting	Without Meaning Per Cent. of Forgetting	With Meaning Per Cent. of Forgetting
After 5 minutes	2.5	0.0	8.8	3.4
After 20 minutes	11.4	4.4	14.6	10.97
After 1 hour	29.3	19.1	22.7	23.05
After 8 hours	52.6	42.1	37.0	38.75
After 1 day	31.1	20.3	28.3	21.01
After 2 days	39.1	33.2	31.9	29.0
After 3 days	——	43.5	——	——
After 4 days	——	45.5	——	——
After 5 days	——	43.5	——	——
After 6 days	50.7	57.6	42.4	42.0
After 7 days	——	50.0	——	——
After 14 days	59.0	70.0	46.1	49.4
After 21 days	62.2	52.4	49.5	47.3
After 30 days	79.8	76.1	66.2	75.7
After 60 days	——	——	94.3	85.4
After 120 days	97.2	——	——	——

this thesis was in progress (1903–04) P. R. Radossawljewitsch was also studying forgetting. By having twenty-seven subjects, both adults and children, he avoided the individual character of the work of Ebbinghaus. He employed nonsense syllables similar to those of Ebbinghaus; but presented the syllables after the manner of Müller and Schumann, so that the manner of reading them was better controlled. The syllables were fixed on a cylinder that rotated so as to expose one syllable at a time through an opening in a screen. He used also subject matter with meaning. Each series consisted of two stanzas of Schiller's translation of "The Siege of Troy," which the reagents read throughout repeatedly until they could reproduce them twice without an error. Radossawljewitsch believed as did Müller and Pilzecker, that two repetitions gave much greater assurance of association strength than the single correct repetition of Ebbinghaus. Each of these two kinds of subject matter was relearned after various intervals, and the numbers of repetitions in learning and relearning were the measures of gain and loss. As shown by Table II. and the curves (Fig. 3), Radossawljewitsch's results indicate that we forget rapidly at first, then rather abruptly slower, and that the later rate gradually decreases. His curve of forgetting rises slower in the beginning and faster in the later portion than that of Ebbinghaus (see Fig. 3). In the cases of adults and children, with meaningless subject matter and with material with meaning, the association strength at the end of one day was greater than at the end of eight hours or at the end of two days. In the results of Ebbinghaus there was a decrease in the rate of forgetting at about the same point. Radossawljewitsch also found a period of relatively slow forgetting between six days and twenty-one days. These later periods of retarded forgetting have no corresponding periods in Ebbinghaus's results.

Radossawljewitsch verified the results of Ebbinghaus in that long series of nonsense syllables are not forgotten as rapidly as short series. The reasons assigned for this fact are the greater amount of practise that longer series require and the enlistment of better attention by the consciousness of the relative largeness of the task.

Both adults and children were found by Radossawljewitsch to forget material without meaning more rapidly than material with meaning, especially during the first two days. His adult observers forgot ⅓ of the material with meaning in 2 days and of the subject matter without meaning in about 1 day. They lost ½ of the matter with meaning in 7 days, and of that without meaning in 6 days. Within 30 days they forgot ¾ of the poetry and ⅘ of the nonsense syllables. The children lost association strength somewhat faster than the adults; but their curves for the same kinds of subject matter were quite similar.

The forgetting of connected ideas was studied by E. N. Henderson.[2] Among his subjects were school children of grades five, six and seven, high school pupils, university summer school students, college students, and graduate students. He selected as subject matter five very dissimilar passages of thoroughly coherent discourse, such as students of various degrees of development might be expected to learn and later to reproduce in class. His experiments were performed in school rooms. As much of one selection as possible was learned in three minutes, and immediately written. Two days later and four weeks later they again wrote as much of the selection as they could. The measures used were the topics, sub-topics, details and words that were memorized and that were later reproduced. He endeavored to find by means of these results the amounts forgotten within different lengths of time, the relation of age and training to the amount learned and to the amount retained, the relation of the rate of learning to the rate of forgetting, and of intelligence to forgetting. He compared also the ability to retain details with

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[2] "Das Behalten und Vergessen bei Kindern und Erwachsenen nach experimentellen Untersuchungen," Leipzig, 1907.

[3] "The Study of Memory for Connected Trains of Thought," *Psy. Rev.* Monograph Suppl., Vol. V., No. 6.

TABLE III

HENDERSON'S RESULTS

	Ideas			Words		
	Gains	Per Cent. Lost in 2 Days	Per Cent. Lost in 28 Days	Gains	Per Cent. Lost in 2 Days	Per Cent. Lost in 28 Days
Summer students ...	23.1	8.8	13.6	44.2	23.3	32.3
Public school pupils	35.3	4.7	13.2	54.6	10.4	23.5
High school students	38.8	11.5	30.5	48.9	16.7	35.9
College students	39.4	25.5	31.5	53.3	39.0	47.4
Graduate students ..	43.1	23.2	36.5	58.2	32.3	49.7
Average	35.9	14.7	25.1	51.8	24.3	37.8

the permanence of larger topics. As shown by Table III. the rise in his curve of forgetting of ideas is eight times as rapid per day during the first two days as it is per day during the first month as a whole. The forgetting curve for words is nine times as fast in its rise per day during the first two days as it is per day during the first month as a whole. In both ideas and words there is a small irregular increase in the retentive ability from the younger, less mature to the older, more mature observers. Henderson believed this to be due to the greater ability on the part of the older subjects to read and to understand the subject matter rather than to any fundamental difference in memory.

Those who learn most rapidly retain a large percentage of either ideas or words; but the correlation of the two tendencies is not very high.

Two teachers made a list of their pupils in the order of their abilities, and this ranking was compared with the ranking of the same pupils in these experiments. It was found that there was almost no correspondence between these rankings among the pupils of the grammar grades. But in the higher grades there was a close relation. The most advanced reagents were superior to the less mature in grasping and in retaining general meaning. This is probably partly due to the exclusion of inferior minds from the higher classes.

The more mature students lost a larger percentage of words than of ideas. This difference was much greater with the younger, less mature subjects.

From the data of his investigation of memory for paired associates, E. L. Thorndike finds it possible to derive a few important conclusions concerning forgetting. His observers were twenty-two college seniors and graduate students. Each unit of the memory task was the ability to write the English equivalent for a given German word. One hundred or more pairs of associates of this kind were practised one hour. A new list was used each day on which practise occurred until twelve hundred pairs had been repeated.

Then the same lists were practised again. Tests were inserted from time to time. All but two subjects learned more than 90 per cent. of all the words in from 2 to 5 entire rounds. After the twenty-two subjects had practised on the average 38 hours they remembered an average of 1,030 words at the end of 3 days, and 620 words after 42 days. Tests made upon seventeen of these persons on closing the last study period and at intervals after practise show that they forgot approximately .05 within 1 hour, .10 during 3 days and from .40 to .50 by the end of 40 days.[4]

W. F. Book devotes a small portion of his most thorough-going study of learning to the investigation of the permanence of impressions.[5] He uses data from only one subject. The apparatus was a typewriter to which was attached Duprez markers which recorded (*a*) the number of letters, (*b*) the number of words printed, (*c*) the number of shiftings of the carriage, and (*d*) the number of times that is necessary for the observer to look at the keyboard. In order to discover any irregularities in the effort put forth while writing, the pulse record was taken by means of tambours adjusted to the temples of the observer. The subject practised a half hour per day 174 consecutive days with the keys of the typewriter visible. After an interval of five months he practised 60 days with the keys hidden by a screen. During the second period, his copy was a short sentence which he practised 120 times per day until he could write it 100 times per minute. The number of strokes made on the last ten days of this practise were compared with the number of strokes made in a similar manner during a ten days test, five months later, and with the number of strokes during another test, 17 months after the end of the 60 days practise. The average number of strokes per day during the last ten days practise were 1,508. The average of the first test was 1,443 and that of the second test 1,611. If these are the numbers that should be compared, there was a loss during the five months between the practise and the test, but a gain instead of a loss, as one might expect, during the twelve months between the first and second tests. Book accounts for this gain by means of the same theory that he offers in explanation of the plateaus in the curve of learning. He believes that during the 60 days of practise, in addition to the fixing of the right reactions, tendencies to many wrong reactions must have accumulated, and that these tendencies have been eliminated before the second test.

However, by careful inspection of this table it becomes evident that there is a gradual gain during each group of ten days, especially during the second test. Judging also from my experience with the typewriter, there is in each of these tests ample room for gain through practise. During the first test the total number of strokes was 14,424 and during the second test 16,081. This makes a grand total of 30,505 strokes after the completion of regular practise. That the gain is due to practise is even more probable in the light of the fact that the tests serve as reviews of so much practise, of the 174 days of general practise with the keyboard visible and of the 60 days of practise on the same subject matter that was repeated in the tests. Moreover, the repetitions in the tests are quite advantageously distributed for progress in learning. Further evidence for this view is found in his curve of regular practise (p. 80). The curve rises at the diminishing rate characteristic of curves of practise, finally rising between 50 days and 60 days a few more than 100 strokes. If practise had proceeded 20 days longer there is every indication that it would have gone above the point (1,611 strokes) reached by the end of the two tests. The difference between the last day's work in the regular practise (1,698 strokes), and the first day's work in the first test (1,365 strokes), indicates a loss through forgetting of 333 strokes in 5 months. Likewise the difference between the numbers of strokes of the last day in the first test (1,472 strokes) and the first day of the second test (1,390 strokes) gives a loss of 82 strokes in 12 months. There would seem also to be a loss in both these cases if, instead of using one day's work as the basis of comparison, we use the average data of three days. The first difference would be 151 strokes, the second 83 strokes. The ratio of the loss in the earlier period with the loss in the later period according to these measures agrees with most studies of forgetting.

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[4] *Pscychological Review*, XV., pp. 132–135 (1908).

[5] "The Psychology of Skill," Univ. of Montana Pub. in Psychology, Vol. I. (1908), Bul. 53, Psy. Series No. I., pp. 75–79.

Therefore the apparent gain that Book finds in these results can not be shown to exist except when we compare groups of ten days each. These evidences throw considerable doubt upon the need of any explanation other than that of learning, forgetting and relearning.

The problem of Ebert and Meumann[6] was to discover whether subject matter that is readily learned is forgotten more rapidly or more slowly than that which requires greater labor in memorizing. Each of five subjects memorized by the method of right associates a series of 12 and one of 16 nonsense syllables, and by the method of learning a series of successive members throughout, another series of 12 and also one of 16 nonsense syllables. Two observers learned in addition two stanzas each of “The Siege of Troy.” The material without meaning that had been learned was relearned by one observer after an interval of 75 days, by a second after 85 days, by a third after 91 days, by a fourth after 146 days, and by a fifth after 156 days. The matter with meaning was relearned by one subject after 146 days and by the other after 156 days. I have condensed Ebert and Meumann's results for meaningless subject matter into Table IV. The most evident facts about these results is that by the use of one of these methods more of the easier series was forgotten, and by the other method more of the harder series was forgotten. Therefore the method of right associates seems to be better adapted to the sixteen syllable series than to the twelve syllable series. With the other method the reverse appears to be true. It may be noted also that there is better correlation between the length of the interval of delayed recall and the amount forgotten. This is doubtless due to the fact that, not only the series, but also the observers were not the same for any two intervals. The subject matter with meaning learned by the consecutive method was more easily learned than nonsense syllables. As in the case of subject matter without meaning, no forgetting occurred, and the observer with the shorter of the two periods was 25 per cent. more able to relearn a stanza at the end of the interval of delay than at the termination of practise.

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[6] "Uber einige Grundfragen der Psychologie der Ubungsphanomene im Bereiche des Gedächtnisses," *Archiv für die Gesamte Psy.*, 1904, 4, 193.

TABLE IV

EBERT AND MEUMANN'S RESULTS

	Method of Right Associates						Method of Consecutive Members					
	12 Syllables			16 Syllables			12 Syllables			16 Syllables		
Intervals	Learning	Relearn	Per Cent. Loss	Learn	Relearn	Per Cent. Loss	Learn	Relearn	Per Cent. Loss	Learn	Relearn	Per Cent. Loss
75 days	8.0	5.0	37.5	8.0	6.5	18.8	6.0	6.0	0.	8.0	7.0	12.5
85 days	4.0	3.5	12.5	7.0	7.0	0.	7.0	7.0	0.	10.0	7.0	30.0
91 days	12.5	7.5	40.0	7.5	7.5	0.	11.0	10.0	9.1	18.0	12.0	33.3
146 days	1.5	2.0	—33.3	4.0	4.0	0.	4.0	4.0	0.	5.0	4.0	20.0
156 days	8.0	7.5	6.3	5.5	5.5	0.	5.0	5.0	0.	5.0	6.0	—20.0
Gross Av.	6.8	5.1		6.5	6.1		6.6	6.5		9.2	7.2	
Per cent. Av.			12.6			3.8			1.8			15.2

An experimental study of the curve of forgetting was made also with pathological subjects by Ziehen.[7] He used this type of observers because one is justified by the principles of psychopathology in expecting that the ability of most patients to recall what they have learned when they are at successive stages of disease should correspond to the ability of normal persons to recall at different stages of forgetting. He says, ''Investigations have shown that loss of memory images is quite slow for a considerably extended time (ziemlich beträchtlichen Zeit), and then there is exceedingly rapid loss.'' This ''critical point'' of the curve has a position dependent upon the disposition of the learner, the kind of incentive, and other factors.

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[7] “Das Gedächtnis,” Berlin, 1908.

He states that it has been experimentally demonstrated by others and by himself that, from this critical point on, the recent is forgotten more rapidly than the more remote by most of those having memory defects. The few exceptions are in special types of insanity. Ziehen's explanation for this phenomenon is that we recall nothing unless its reproduction is necessitated by some experience that precedes it; and as the old experience has become consciously and subconsciously, or cortically, more connected during the intervening time than has been possible for the recent experience, this new experience is more difficult to recall until it has had time to thus become a more intimate part of the individual.

Moreover Ziehen finds that forgetting is not all passive, but that holes are torn in the memory image, and also older images are modified by the play of newer associations in normal individuals similar to the way in which they are distorted in pathological amnesia.

In none of the other investigations that I have been able to find does the curve of forgetting have the form described by Ziehen. The nearest approach to it is the curve found by Radossawljewitsch, which rises slowly during the first five minutes, and then much more rapidly. I believe that the solution of problems in arithmetic, which he used as one form of subject matter, usually depends largely upon a fundamental principle and a group of related, subordinate principles. When the fundamental principle finally passes below the threshold of recall, the dependent principles would thereby lose suddenly a large part of their association strength. But this explanation could scarcely be applied to his other subject matter, six, eight and nine place numbers. Ziehen's description of his method and results is not complete enough to permit much use to be made of his conclusions.

Several more recent investigations of kindred problems have led to conclusions concerning forgetting. The following declaration is made by A. Renda:[8] ''Forgetting is not merely an accidental characteristic of mental function, but is the result of an active process of dissociation. It is a means by which consciousness gets rid of redundant material." Pieron[9] says that forgetting is like auto-catalysis in chemistry in that it is a change that ensues in a memory image by reason of the presence of transforming agencies in the image itself. These views have evidences, but no counter-evidences in the results of the other investigations previously quoted.

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[8] ''L'oblio saggio sull' attivita selettiva della coscienza,'' Torino, Bocca. 1910, p. 229.

The results of Ebbinghaus and Radossawljewitsch resemble each other in that the rate of forgetting is more rapid at first than later; but they disagree in the amount of difference between the early and the late portions, in the degree of abruptness in the change, and in the other irregularities in the curve. Ziehen's curve seems to be radically different from all the others. Several of the investigators have found data for too few intervals to furnish much assistance in harmonizing these curves until there is additional investigation in the same field.

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[9] "L'evolution de la memoir," Paris, 1910.

CHAPTER II

The Problem and the Method

Investigation has revealed the fact that two kinds of results arise from the insertion of intervals into an act of learning. If recall is delayed, the association links become weaker. If practise is interspersed with periods of relative inactivity, the repetitions have greater value. The most advantageous degree of the distribution of practise through the interjection of periods of rest has been theoretically but not experimentally determined. Nor is the cause of this phenomenon much more than a question under discussion. Even the practise curve has been determined only as to its general form, and there is disagreement concerning its details. Moreover in the case of forgetting, as has been shown by the previous chapter, not only the details, but also the general trend of the curve is in dispute.

The results of investigation make it probable that we forget faster immediately after practise than later. The earlier part of Radossawljewitsch's curve rises more slowly and the latter part more rapidly, however, than that of Ebbinghaus, and has several stages of slow forgetting that are not present in the curve of Ebbinghaus. Explanations of these differences have been either theoretically proposed or are merely foreshadowed by the results.

This thesis is an endeavor to study the same field with several kinds of subject matter and various methods. The fundamental problem is whether all forgetting is governed by the same general law. The secondary aim is to discover, if possible, why the results of various investigations do not more fully agree.

The first group of experiments reported in this thesis was performed in 1903 in the University of Chicago, and was discontinued after five months because of the demands of a new position. In the mean time Radossawljewitsch began his investigation of practically the same problem. His work was published in 1904. The second group of experiments of this thesis was performed with entire classes in the Indiana State Normal School in Terre Haute, and by reason of its nature, it covered a long period (1904–09). The last three groups were performed under the direction of the department of psychology at Columbia University during 1909 and 1910.

Previous researches have shown incidentally that learning and forgetting take unlike forms and progress at varying rates with the slightest differences in subject matter and in types of learners, with relatively trivial deviations in method, with changes in health or in time of day, as well as with an increase or a decrease in the periods between practise and recall. However, both phenomena have shown constant relations between controlled conditions and consistent results. Therefore, the choice of subject matter and of methods has been with this end primarily in view. It should be possible to isolate a factor of this nature for study without departing from the conditions of learning in daily life including those of school. Facts are no less scientific when practical. The derivation of principles from that source paves the way for their most convincing verification through successful application.

As simple subject matter without meaning can be learned easiest and most rapidly by the so-called "trial and success method" and complex subject matter with meaning by more rational methods, there is likely to be some difference in the manner in which they are forgotten. The content to be learned will, then, be simple and complex material similar to that of practical life.

As far as possible such subject matter was chosen as would appeal to but one sense department, and would not be a stronger stimulus to persons of one age, sex or race than to those of another age, sex, or race. In the first group of experiments the subject matter was a series consisting of one muscular movement repeated many times. In the second group a number of sensations constituted the series. The subject matter in the third group was complex. Each member of the series of stimuli was responded to by a corresponding member of a series of movements.

The methods were also made to correspond as far as possible with those which are most serviceable in daily life. All conditions were kept constant except the intervals between practise and recall. The short periods that were necessary for the making of records and to readjust apparatus were timed carefully so as not to allow any differences in the association strength or in the values of new repetitions owing to variations in the distribution. Sufficient control was exercised to make the results comparable; nevertheless, the limitations were so few that after the experiments were well begun, the reagents were unconscious of restraint. The stimuli were presented to the most used sense, vision, and were responded to by movements. Series were practised as a whole, as in everyday life rather than piecemeal as is too often done in school. The observers were all adults with no very individual tendencies. The details of method in the individual experiments will be discussed in their particular chapters.

CHAPTER III

The Forgetting of a Relatively Simple Motor Act

The experimental work in this chapter was performed in the University of Chicago during 1903–04. Although the data can be of little value in the determination of the curve of forgetting they throw some light on the conditions of learning. The earliest plan was to begin the study of forgetting by using a series consisting of the repetition of one act in which the motor element is highly dominant. Throwing was chosen as being a distinctly human acquisition that is probably not based on an innate tendency as such, and that is typical of common forms of manual skill.

It soon became evident that it is more difficult to secure accurate scores in throwing than it is in other kinds of target practise. In an effort to obtain reliable scores, the target was made to undergo several transformations. The final and most successful target consisted of hollow cylinders made of wire mosquito netting of diameters corresponding to the diameters of the circles used in the targets of most of these experiments. These cylinders were closed at one end, and strengthened with a ring of stiff wire at the open end. They were placed within each other in the order of size, and supported so that the curved wall of one was equidistant from the corresponding walls of the others. The open end of this compound cylinder was placed toward the thrower so that one and three fourths inch wooden balls, when thrown, would pass into one or another of the cylinders according to the accuracy of the throws. When a projectile struck the edge of a cylinder, it fell into the next larger one, because each cylinder was shorter than the next larger, and adjusted so that its open end was five inches further from the thrower than that of the next larger cylinder. The entire target was mounted so that a projectile rolled toward the closed end of the cylinder into which it had been thrown and into a trough-like crease or groove in the lower side of the cylinder where it took its place in line with others that scored equally with it. Along each crease was read directly the score made by lodging any specific number of projectiles in that division of the target during a series of one hundred throws. After having read the scores, a small metal plate, that covered an opening opposite the rear of each groove, was swung to one side to allow the balls to roll out of the target in preparation for another series.

It was readily ascertained by preliminary experiments that, when other conditions were constant, series thrown by the right hand, by the left hand, in the under-hand, in the over-hand, and in the direct modes did not improve at parallel rates with equivalent amounts of practise, nor did they decline equally during the same interval. Successive series with one hand and with one kind of throwing movement were adopted as the most nearly comparable.

One reagent was a university professor, and ten other observers including the writer were graduate students in psychology. Each reagent was free to throw in a manner of his own choice except that he was required to continue throwing in the same manner throughout a group of experiments. The throws were made to coincide with the strokes of a metronome bell. Further preliminary experiments were performed to find the rate of throwing that yielded the greatest progress. Five persons were found to have individual rates at which throws could most advantageously succeed each other. These rates were always as rapid as projectiles could readily be picked up and thrown. Later each of two reagents performed one thousand throws with each of the following intervals. There are too few subjects in this preliminary test, to serve as conclusive evidence that with this kind of material, the shorter the interval the more rapid is the progress in learning; but these evidences indicate a likelihood that Bergström's principle, "the acquisition and retention of associable words varies approximately as the interval between the members of a series," may apply only to complex subject matter with meaning. In relatively meaningless matter, for example in throwing, the formation of a series out of the mere repetition of an act, the progress seems to vary approximately inversely as the number of repetitions within a given time. The only limits to this in throwing were that the speed should not exclude the accurate picking up of projectiles and the aiming and proper swinging of the arm in throwing, and the avoidance of fatigue. This would not warrant the division of subject matter into two distinct classes to be learned in two very different ways; but it would mean that the intervals between members of series and between entire series should depend upon the degree of complexity of the series. Ebbinghaus states

TABLE V

THE VALUE OF INTERVALS DURING PRACTISE

	30.0 Sec.	60.0 Sec.	120.0 Sec.	180.0 Sec.
Per cents. gained	49.2	24.9	6.3	6.7
Per cents. gained	57.8	14.3	23.2	10.0
Average gained	53.5	19.6	14.8	8.4

that the more repetitions of nonsense syllables he could crowd into a given time, the quicker he could learn them. Lottie Steffens found that with her subjects rapid learning was not necessarily conditioned by many repetitions within a short time. Moreover it has been shown that with simple subject matter the trial and success method, as it is called, produces quicker, surer results, whereas it has been repeatedly demonstrated that subject matter with meaning is learned more economically by thinking one's way through at first. Because of the results gained in these tests, the throwing was done as rapidly and as persistently throughout each period as the picking up of projectiles and the avoidance of fatigue would permit. Other preliminary tests made it evident that a target to be thrown at by inexperienced men and women at a distance of six meters, should be about a meter in diameter. It also became evident that the projectiles should, if possible, be adapted to the size of the thrower's hand; but that an average size would be about one and three fourth inches in diameter. Slight inequalities in the weights of projectiles used resulted in relatively great deviations in scores. The general effect of practise made the point at which the practise of each series began a variable quantity. The influence of this defect was reduced somewhat by finding what per cent. of the gain was lost through delay.

In the principal experiment of this group such meager gains were made in throwing one hundred times that the loss due to delayed recall could not be measured with any degree of certainty. Persistent throwing several hours per day during a series of days yielded more commensurate gains; but the decrease in association strength was proportionately slow. In order to find whether the small scores were due to a defect in the method or to the inability of the psycho-physical organism to habituate itself rapidly to this kind of reaction, the apparatus was so modified as to record the force as well as the direction of each throw. Back of each corner of a square wooden target of one meter side was fixed a large tambour with its three inch rubber membrane on the side towards the wall, against which the target was suspended by ropes. A screw was driven into the wall in such a way that its head, which was two inches in diameter, rested against the middle portion of the membrane. The air chambers of these tambours were connected by means of tubes with one tube which led to a Marey tambour. When a projectile hit the target, the momentum with which it struck was recorded on a revolving kymograph drum by the pen of the Marey tambour. The throws were at first very unequal in force, but they rapidly and regularly became equal as practise proceeded, and with an equal degree of regularity they became unequal in intensity with longer and longer intervals of forgetting (Fig. 1). Therefore much more progress was being made in learning to throw than was evident in terms of control of the direction of the throwing movements. As the increase or the decrease in the amount of energy expended is more immediate and more simple than the guidance of movement, its mastery is probably more easily acquired in games and in work.

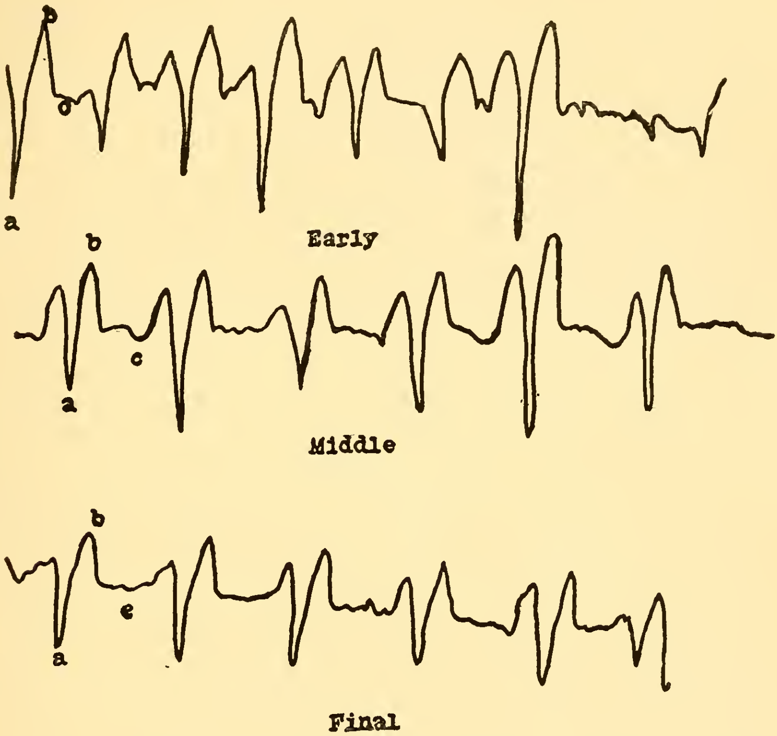

FIG. 1. Pantographic copies of records of the force of throws. Points *a* were made by the hitting of the target. The record of the greatest recoil and of the lesser recoils are indicated by *b* and *c* respectively. The ''early'' curves were made near the beginning of a seris of 100 throws and the ''final'' curves were near the end of that series.

The complexity of the control of movement in three-dimensional space was evident in the fact that the spots that recorded the ''hits'' were arranged in the form of an ellipse with its long axis parallel with the motion of the arm. This axis shortened much faster than the other axis as skill increased, and was relatively short with persons who were accustomed to throwing in the manner used. Skill in throwing is therefore largely ability to release a projectile at the proper moment. All of the reagents reported that they found themselves strenuously endeavoring, while throwing, to avoid "wild" throws, that is, "hits" beyond their usual limits, and also were conscious of trying to strike the bull's-eye. Sometimes one of these purposes and sometimes the other was uppermost in mind. Total scores showed later that near the boundary of each reagent's field, was a ring-like area in which the "hits" were more numerous than in closely neighboring portions. In the region of the bull's-eye there was a somewhat similar sudden increase in the number of "hits." "Wild" throwing was usually due to the momentary straying of the attention or to loss of confidence owing to previous "wild" throws. After about fifty throws of a practise series, the score almost always decreased, and the "wild" throws increased unless the bull's-eye was varied in color or in some other quality to overcome this inconstancy of attention. The necessity of this renewal of the stimulus was probably due to the monotony of a series that was merely the repetition of one sensori-motor act.

The larger the number of muscles involved in a psycho-physical act, the greater is the number and variety of possible reactions, and therefore the slower is the progress. The rate of learning is more rapid in the use of the preferred hand than in the use of the other hand.

In so far as the results of this group of experiments have value, they indicate that the conditions of progress in the study of forgetting are: a series consisting of varied members preferably with meaning, rather than a series composed of repetitions of one short interval between simple reactions and of longer intervals the more complex the reactions; attention kept at its highest intensity, if necessary, by means of devices; as small a group of muscles as possible, muscles previously coordinated in other acts but not in the one that is being practised.

CHAPTER IV

THE FORGETTING OF SENSATIONS WITH RELATIVELY LITTLE MEANING

AFTER having spent several months in the almost fruitless efforts to modify the methods and apparatus of the experiment described in the previous chapter, I endeavored to retrieve the loss by performing a group of experiments during spare moments while teaching. This work is a study (1) of how meaningless, relatively simple subject matter decreases in association strength, (2) of the manner in which students often forget what they learn in class, and (3) of how students recall under class-room conditions.

The experiments were performed with entire classes of students in the Indiana State Normal School. These students had largely attained the degree of physical and mental maturity of college sophomores. Nearly one third of them were men, and more than two thirds were women.

The subject matter was a consecutive series of nine consonants that had been found by experiment to be about equally difficult to remember. Vowels were omitted in order to avoid the possibility of combining members of a series into syllables. Consonants were chosen rather than numerals; because consonants furnish an opportunity for recall not only by reproduction but also by identification; whereas the selection of nine digits from among the few would not be a fair test of recall. Most persons are habituated in the use of numbers, and even of letters in calculation, and are familiar with the employment of letters as initials and symbols without definite reference to what they symbolize; but, as a rule, they do not use words and syllables in that manner. Therefore, letters have not such a strong tendency as words or syllables to suggest meaning. For these reasons a series consisting of letters was chosen as a type of meaningless content. These letters were presented successively, and each series was repeated as a whole. Each consonant in the series was presented one second with no perceptible interval between the presentations. The letters were one and one half inches in height, and were arranged at intervals of three inches in a vertical column on a sliding screen. In front of the letters was a stationary screen with an opening through which one of the letters at a time could be seen. On the back of the sliding screen opposite each letter a small roller was fixed with its axis perpendicular to the surface of the screen.

These rollers were placed alternatingly on two parallel lines which were drawn vertically along the middle of the sliding screen. Behind this screen a pendulum was suspended at its middle point. This pendulum carried a bob at each end. Attached to the front of the pendulum rod was a metal half ring with a radius of about two inches. Its concave side was upward and its center coincident with the point of support of the pendulum. It was so placed that one of the rollers resting upon it supported the sliding screen. When owing to the swinging of the pendulum, this roller passed through an opening at the middle of the half ring, it allowed the screen to fall until the next roller was caught by the half ring. One second later it, in turn, fell through the opening. It is evident that while a roller rested on the half ring, one of the letters was being exposed through the slit. The half ring was padded at places where the rollers first struck, in order to diminish the noise resulting from the impact. Three additional rollers permitted the swings of the pendulum to become regular before the exposures began. As one series was used for all intervals of delayed recall each group of students served for only one interval. Preliminary experiments indicated that this plan would be better than that of using different series and of having each class serve for several intervals. Besides, as the Indiana State Normal School is not an institution of research, I preferred not to use much time for an experiment after it ceased to be a profitable exercise for the students. However the whole quantity of results shows that it would have been better to have experimented with several series with the same subjects.

It was not a totally new experience for the students in these classes to take part in psychological experiments; but there was enough unusualness about it to increase the tendency to vocalize the letters. They were therefore urged to abstain from moving the vocal organs. This reduced the action to about its normal degree. It was made clear that if any one failed to do honest work, he would gain nothing, and that the science of psychology would probably lose. Even those did faithful work who were known by their teachers to need watching in examinations. The mode of procedure was as follows: Each reagent was given a slip of paper bearing a number. After the presentation of the entire series the reagents of one group were allowed two minutes during which to write the letters that could be remembered, and as far as possible to place them in the order in which they had been presented. They then folded the papers in each case so as to conceal during the remainder of the experiment, the letters which they had just written. In this manner, the presentation of the same series, the writing, and the folding were performed six times; but any reagent who was moderately sure before any presentation that he had correctly written the series withdrew from the experiment by occupying himself with some other interest or duty. When all had finished, they recorded their physical condition as good, medium, or poor. The papers were then collected.

After a period of from one to twenty-eight days, each subject was supplied with paper on which he placed the number that he had found on the paper given him when the experiment was begun. This made it possible for me to compare his two papers. He then reproduced and recorded the letters and their order in so far as he was able. To this he added the information that was necessary in determining the value of his results. One item was the condition of his health. Another was whether any part of the series had been recalled during the interval, and whether he had been able to crowd it out by turning his thoughts to more interesting matter. He stated also whether he had associated the letters with initials or words and whether he had used rhythm or had vocalized.

Another group of subjects were allowed one and a half minutes to select the letters of the series from among the eighteen consonants of the alphabet and a half minute in which to arrange in the original order the nine consonants of the series, which were shown them in mixed order. Thus were obtained data for the comparison of the methods of selection, reproduction and reconstruction.

The tables do not include the results (*a*) of students who were present for only one part of an experiment, (*b*) of the few who did not understand how the experiments were to be performed, (*c*) of the subjects who recalled more than one letter of the series during the interval of forgetting, (*d*) of the reagents who associated some of the letters with initials or other subject matter, (*e*) of one observer who was not strictly honest in her work, and of several who were accidentally aided in reproduction, (*f*) of reagents whose health conditions were not normal or whose sight was too defective to produce reliable results. After these had been dropped, the results of 756 subjects constituted the Table VI., and of 348 constituted Table VII. The subject matter that could not be recalled after intervals of one to twenty-eight days is shown in terms of reproduction in Table VI., and in terms of recognition and reconstruction in Table VII. In both tables each gross measure is the average of the number of errors after the interval of delay opposite which the measure stands. The per cent. of the given subject matter that was forgotten is in a companion column. As there were nine letters in each series, nine omissions were possible. Therefore each omission was valued at 1/9 of 100 per cent. It was expected that insertions would occur only when opportunities for insertion were made through omissions; but inspection and calculation show that there is no correlation between the omissions and the insertions. Hence each letter inserted was also valued at ⅑ of 100 per cent. There is no general agreement concerning the methods of evaluating errors of order. Every plan is based upon a theory of the manner in which members are associated in a series. In the case of the series of letters whenever one member was one removed from its given place in the series there were on an average as many evidences of weakness in the association links as when one member was from two to eight removes from its proper locality. Therefore in this group of experiments one letter out of place was counted one error of order regardless of the number of letters between it and its proper locality.

TABLE VI

THE METHOD OF REPRODUCTION

	Omissions		Insertions		Errors of Order		Totals			
Intervals	Gross	Per Cent. of 9 Errors	Gross	Per Cent. of 9 Errors	Gross	Per Cent. of 9 Errors	Gross	Per Cent. of 27 Errors	Av. Per Cent. Per Day	Observers
1 day	1.1	12.2	0.5	5.6	1.4	15.6	3.0	11.1	11.1	41
4 days	1.1	12.2	0.6	6.7	2.4	26.7	4.1	15.2	3.8	114
7 days	1.6	17.8	0.6	6.7	3.1	34.4	5.3	19.6	2.3	140
14 days	2.6	28.9	0.9	10.0	2.3	25.6	5.8	21.5	1.5	298
21 days	2.2	24.4	0.9	10.0	2.6	28.9	5.7	21.1	1.0	123
28 days	2.0	22.2	1.3	14.4	2.4	26.7	5.7	21.1	0.8	40

TABLE VII

THE METHODS OF SELECTION AND RECONSTRUCTION

	Selection				Reconstruction				
	Omissions		Insertions		Errors of Order		Totals		
Intervals	Gross	Per Cent. of 9 Errors	Gross	Per Cent. of 9 Errors	Gross	Per Cent. of 9 Errors	Gross	Per Cent. of 27 Errors	Observers
1 day	0.7	7.8	0.4	4.4	1.9	21.1	3.0	11.1	21
4 days	0.9	10.0	0.4	4.4	2.9	32.2	4.2	15.5	100
7 days	1.3	14.4	0.4	4.4	3.7	41.1	5.4	20.0	40
14 days	1.8	20.0	0.6	6.7	2.8	31.1	5.2	19.3	55
21 days	1.6	17.8	0.7	7.7	3.1	34.4	5.4	20.0	92
28 days	1.9	21.1	1.3	14.4	2.9	32.2	6.1	22.6	40

Table VI. contains the data obtained by the method of reproduction. Table VII. consists of results of the methods of selection and of reconstruction. Table VII. was produced in one group of ex-

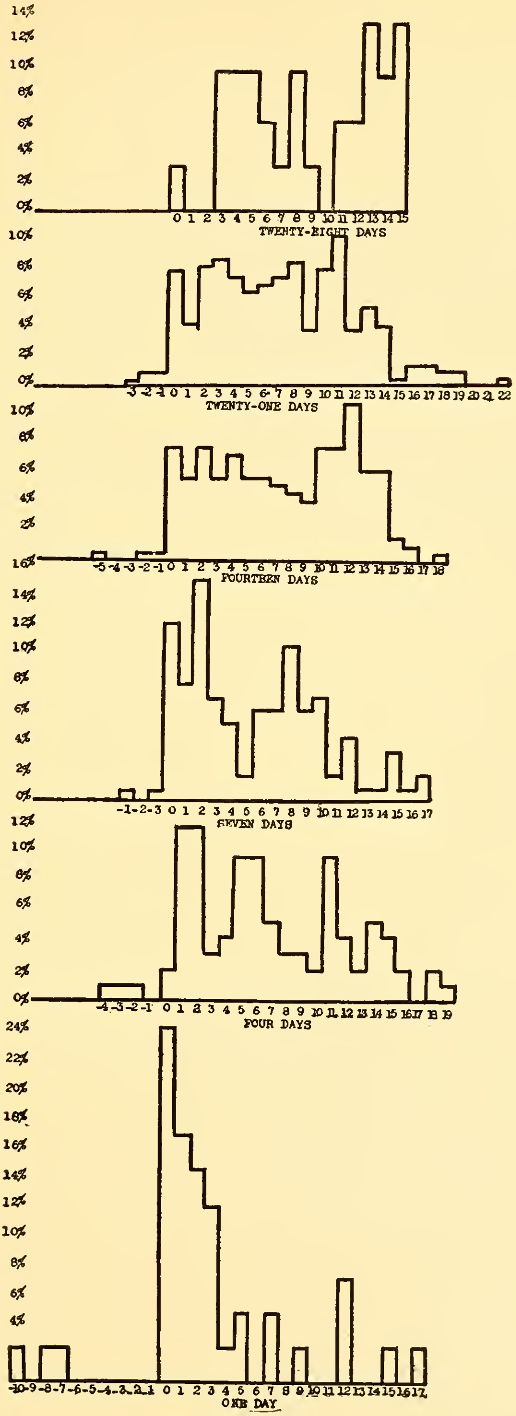

Fig. 2. Surfaces of distribution.

periments and is therefore not given as two separate tables. In both Tables VI. and VII. the total per cent. of errors is not, like the total gross errors, the sum of the errors in the three preceding columns; but it is the per cent. of the total twenty-seven errors that are possible in each experiment.

The errors of Table VI. increase rapidly during the first fourteen days. During the remainder of the twenty-eight days no additional errors are evident in the results. According to the method of reproduction, therefore, ⅓ of the gain is lost by the end of the first day, and ⅔ within 14 days. By the method of selection also the errors are found to increase rapidly for 14 days with few additional errors thereafter; but the errors of the insertion of letters increase rather gradually to the end of the period studied. Seven days is the limit of rapid forgetting according to the method of reconstruction. The loss of association strength after seven days is rather slow. The increase in errors of insertion is greater than in errors of omission, and in errors of order.

The surfaces of distribution (Fig. 2) were constructed from the errors in the method of reproduction and therefore correspond to Table VI. As the numbers of cases reported in connection with the six intervals are quite unequal, each surface is made on the basis of percentage of error. There would be no cases, of course, with less than zero errors, were it not that for unaccountable reasons, a few individuals made more errors at the close of practise than during the test. A large percentage of individuals made no errors when the interval was one day; and this percentage decreased with the lengthening of the interval, as shown by the mode that was at zero when the intervals were shortest, and that arose to the larger measures as the intervals lengthened. But there seems to be another mode that fluctuates somewhat within the range 8 to 12 errors, and has a tendency towards larger measures as the intervals lengthen. This indicates that the subjects who participated in these experiments may have belonged to two distinct groups. Most of the members of one group made from zero to 4 errors, and those of the other group from 8 to 12 errors when the delays are from 1 to 28 days. If under some circumstances the cause of one of these modes, and under other circumstances the cause of the other is dominant, considerable differences in the curve of forgetting, such as show themselves between the results of different investigators, might easily arise. Therefore I endeavored to find two or more causes of loss in association strength. The most profitable ones are two or more groups of reagents who do not react alike under a given set of conditions. The mode of reaction must necessarily be one that increases the number of errors of one of the types of observers and either leaves the errors of the other type unchanged, or decreases them, or increases them at a different rate. Even though all reagents had been instructed to practise no more after they were moderately sure that they had written all the letters in their correct order once, only 24 per cent. of them ceased at the stage of practise desired; whereas 39 per cent. exceeded this limit, on the average, by a little more than 1½ repetitions, and the remaining 37 per cent. believed that they had reproduced the letters in their proper order before they had done so. The data of these three groups were made into separate tables and into corresponding surfaces of distribution with the hope of thus separating the two or more types that are responsible for the existence of more than one mode. But the general form of surfaces representing the segregated groups bore the bi-modal character of the composite surfaces.

Guided by numerous clues of the above type, a group of experiments was performed in order to discover the cause of this bi-modality. The observers were Normal School students, distributed by influences that had nothing to do with their individual abilities into three sections of a class in psychology. The method of experimentation was similar in many respects to that of the other group described in this chapter. Each paper was made to indicate whether the reagent was a man or a woman, white or colored, and in good, medium, or poor physical condition on each day of the experiments. The studies being pursued, and an accurate estimate of the average number of hours and fractions of hours per week spent in study were also reported. The interval was seven days in all experiments in this group. The reagents in section *A* were allowed to have the impression that the experiment was complete at the end of practise. Sections *B* and *C* were told that they would be required to reproduce the series later, and that they should therefore avoid discussing the experiment and should have a more interesting subject matter ready to absorb the attention whenever the series entered the mind. Section *C* was instructed to avoid the use of devices in learning. Section *B* was directed to use rhythm with three members of a series to the measure. No mention of devices was made to section *A* until practise had been completed. After practise and after recall, subjects of all sections recorded their introspections regarding the use of rhythm, association, and other aids.

Tables VIII. and IX. make possible a general comparison of sections *A, B,* and *C*. The expectation of the final test did not decrease the number of errors made by the members of section *C,* as they made a larger number of mistakes than the observers in section *A,* none of whom knew that this test was to be given. The difference between the results of these two sections may have been due, however, to the other differences in the method of conducting the experiment, the permission and prohibition of devices. There is evident a secondary mode in the neighborhood of 4 in the total distributions, and also in all partial distributions of sections *A*, *B*, and *C*, that deviate sufficiently from the primary mode near zero and one. The cause of the bimodality that we are studying in this group of experiments is not evident therefore, in any factor that is shown in Tables VIII. or IX.

TABLE VIII

CENTRAL TENDENCIES AND DEVIATIONS

	Omission			Insertion			Order			Totals		
	A	*B*	*C*	*A*	*B*	*C*	*A*	*B*	*C*	*A*	*B*	*C*
Averages	0.91	0.4	1.08	0.25	0.2	0.3	1.75	0.8	1.65	2.92	1.4	3.04
Medians	0.79	0.32	0.63	0.38	0.42	0.26	0.13	0.17	1.0	3.3	0.62	0.83
Modes	0	0	0–1	0	0	0	1.0	0	0	1.0?	0?	0–1?
Av. Dev.	0.94	0.59	0.81	0.44	0.35	0.42	2.02	0.96	1.49	1.79	1.65	2.4
Probable Errors										1.04	0.9	1.92

Both groups of experiments described in this chapter were performed during a prosperous industrial period. As is usual under such circumstances, fewer of the most capable young men were attracted to the schools in which preparation is made for the ill-paid vocation of the teacher. Consequently, in general, the women in the Indiana State Normal School were doing school work of a somewhat higher grade than was being done by the men. Men and women were, therefore, two groups that might forget at different rates. As the larger number of errors would be expected to appear in the results of the students whose class grades were the lower, and as about one student among three was a man, it seemed probable that the men's errors constituted the secondary mode. However, as shown in Table IX., the women made nearly the same per cent. of errors as the men. Therefore the two modes are not due to the difference in sex.

TABLE IX

THE SEXES AND FORGETTING

	Men		Women	
	No.	Errors	No.	Errors
Group *A*	3	6	29	93
Group *B*	2	7	13	14
Group *C*	2	7	21	63
	7	20	63	170
		Av. = 2.86		Av. = 2.89
				Dif. = 0.03

There were not enough colored reagents to have as great an influence as was shown by the surfaces of distribution.

Sixty-nine per cent. of group *A* and 38 per cent. of group *C* used rhythm. Table X. shows that these observers retained 16.12 per cent. more of what they had learned than was retained by members of the same groups who did not use rhythm. Group *B*, all of whom used rhythm as directed, made 57.23 per cent. fewer errors than those who were able to avoid rhythm in group *C*. However, if these facts account in any measure for the bimodality that is found in the results of this chapter they can not be the sole cause; for the distribution of group *B*, in which all rhythmized, contains as much evidence of bimodality as that of groups *A* and C (Table VIII.). Rhythm reduced omissions about ⅔ in number, insertions ⅓ and errors of order ½. Therefore it prevents omissions especially and aids much in retaining the order of a series. It is possible that this would throw the errors into two groups.

TABLE X

THE USE OF RHYTHM

	Rhythm				No Rhythm			
	Omissions	Insertions	Order	Totals	Omissions	Insertions	Ordor	Totals
Group *A* ...	1.07	0.25	1.6	3.0	1.00	0.83	2.33	4.2
Group *B* ...	0.33	0.1	0.9	1.33				
Group *C* ...	0.93	0.33	1.93	3.13	1.33	0.22	1.56	3.11
A and *C* ...	2.00	0.58	3.53	6.13	2.33	1.05	3.89	7.31
Average	1.00	0.29	1.77	3.07	1.17	0.53	1.94	3.66
				Differences =	.17	.24	.17	.59
Gain through rhythm						16.12 per cent.		

In order to find whether the two modes could be due to differences in sensory type, an effort was made to determine in a general way whether the subjects were predominantly visual or auditory. Twenty numbers of three digits each were alternately either pronounced or exposed to their view. The period of presentation, which extended from the end of a pronunciation to the beginning of the next pronunciation or from the end of an exposure to the beginning of the next exposure were equalized by the means of a metronome. The observers were instructed to keep the sound of each spoken number in mind throughout its period and to look at each visible number during its entire period. Each period was four seconds in length. After the presentation of the whole series, all the numbers that could be remembered were written in one column. The number of members of the visual and of the auditory presentations that were written correctly determined the type. Only those whom the results designated as pronouncedly of the one type or of the other were included in Table XI. An inspection of the table will show that there is no relation between visualizers and audiles that indicates that either type learns much faster than the other. But when both avoid rhythm (sec. *C*) the visualizers forget 150 per cent. more than do the audiles. When both use rhythm (sec. *B*), the auditory type loses 350 per cent. more than the visualizers. These reactions unite in the verdict that both are influenced by rhythm but that audiles depend more upon rhythm than do visualizers. This is in agreement with those theories of rhythm which assign a larger place to hearing than to sight as a means of acquisition of the rhythmic tendencies of consciousness. Table XII. shows the relations that were found between the rate of learning and the rate of forgetting. In collating this table, individuals were classed as slow, medium or fast on the basis of the repetitions that were necessary in learning a series. This classification corresponded quite closely with the time spent in the preparation of lessons and with my knowledge of the kind of work done by each student for other teachers as well as for myself.

TABLE XI

SENSORY TYPE

	Auditory			Visual		
	No.	Errors	Av. Errors	No.	Errors	Av. Errors
Group *A*	4	17	4.2	23	71	3.1
Group *B*	4	7	1.8	5	2	.4
Group *C*	6	12	2.0	7	36	5.1

TABLE XII

RATE OF LEARNING

	Rapid			Medium			Slow		
	No.	Errors	Av. Errors	No.	Errors	Av. Errors	No.	Errors	Av. Errors
Group *A*	20	58	2.6	7	24	3.4	5	17	3.4
Group *B*	7	3	0.4	4	2	0.5	4	16	4.0
Group *C*	9	27	3.0	7	23	3.3	6	19	3.2
	36	88		18	49		15	52	
	Average		2.44	Average		2.72	Average		3.47
	A.D.		1.7	A.D.		2.3	A.D.		2.0
	P.E.		.04	P.E.		1.7	P.E.		1.7

The table shows that the rapidity of learning and the rapidity of forgetting were in inverse ratio with each other. The slow learners forgot 42.3 per cent. more during the seven days than the rapid learners. The average deviations and probable errors of the losses in association strength were much smaller in the case of the rapid learners than in case of the slow learners. Hence rapid learners are more alike in their manner of forgetting than are slow learners. This is no doubt due to the greater regularity and smaller number of wrong reactions which are the essentials of speed. All gained through the use of rhythm except the slow learners. However, two modes are evident in nearly all of these distributions.

By means of rhythmical repetition (sec. *B*), the rapid learners decrease their errors due to forgetting 87 per cent.; the medium learners also diminish their errors nearly 85 per cent.; but the slow learners lose 25 per cent. more. These variations do not make a gradual transition from large through medium to slight change in rate of forgetting; but we can state with some degree of assurance that rhythm aids rapid learners, and hinders slow ones.

There were differences in the rates of forgetting, however, between rhythmizers and non-rhythmizers, between audiles and visualizers, and between rapid and slow learners. Moreover, when visualizers and rapid learners used rhythm, there were decided diminutions in their errors; but when they avoided rhythm, they increased their errors; and when audiles used rhythm, there was also a slight falling off of errors; but when slow learners used rhythm, the errors were increased about ⅓. According to these results the two groups of observers could be either rhythmizers and non-rhythmizers, or audiles and visualizers, or slow learners and rapid learners, were it not that in each case a secondary mode is apparent in the neighborhood of 4 errors. This appearance of a secondary mode whenever distributions extended from zero to 4, together with the appearance of a similar bimodality in the distribution of Ebbinghaus for 2 days, 6 days, and 31 days (see Table I.), and also my failure in grouping the measures so as to find the cause in too few measures, are indications of a difference in results that is worthy of further investigation.

CHAPTER V

FORGETTING OF SENSORI-MOTOR EXPERIENCES

IN previous groups of experiments the investigations have been made with simple subject matter. In one case, the series consisted of a single motor reaction repeated a number of times. In another case, the members of the series were varied. Throwing was chosen for the earliest investigation as representative of a usual type of simple manual skill. The aim of a second study was to find the rate, and the manner in which simple sensory subject matter that has no meaning to the learner establishes and loses association strength. In the experiments discussed in the present chapter, the reaction to be acquired is highly complex. An effort was made to combine in it as many as possible of the conditions essential to the delineation of the curve of forgetting and to the comparison of the methods of securing data to that end.

In order to learn and to forget in a thoroughly typical way, I endeavored to choose one of the common tasks of learning in which the reaction was clearly sensori-motor, with the intellectual element present and dominant in the early stages of learning but subordinate later. This kind of material seemed desirable because investigations have shown that in order to exemplify the most usual procedure in learning, the early stages should demand much more than the mere sensory and motor reactions. The later stages should progress most rapidly when thought is most actively supplying devices to abbreviate the acts, and to rectify errors. At last, the presence of a stimulus should result in motor response more readily without the intervention of thought than when thought is present. As most learning passes through these stages, numerous examples were at hand; but typewriting was believed to fulfill the requirements best owing to the fact that there are necessarily not only pairs of associates consisting of members of a copy as stimuli to be related to members of a keyboard, but also a consecutive series, each member of which is a pair of associates because the letters are combined as words and sentences and the position of each key becomes known through its direction and distance from every other key as used in a series. Owing to these complexities the learning of typewriting requires much intelligent guidance. It is typical of the most practical accomplishments of the pupil in school, such as penmanship, reading aloud, drawing, and the fundamental processes in numbers. The operation of a typewriter was therefore chosen as the subject matter of this group of experiments.

The typewriter was a Remington, No. 6, with the writing invisible. A screen was so placed as to conceal the keyboard from the reagent and thus to insure his confining himself to the so-called "touch method." On the screen at about reading distance from the reagent was placed a copy of the series to be learned. A paper in the machine preserved the evidences of the keys which had been struck. The subject sat in an office chair which could be adjusted to his most convenient height. A stop watch was used by the experimenter to measure the time required in writing the series. Whenever *B,* the writer, served as subject, it was necessary for him to perform the duties of experimenter also. The watch was then operated by means of the following device: A small wooden base was clamped near the edge of the top of the typewriter desk. Two metal brackets mounted on this base supported a seven inch wooden lever in such a way that it could be rotated about its middle point. Between one arm of the lever and the base, the watch was held on edge, with its stem in a small round depression in the lever, and the edge opposite the stem was fitted into an oblong depression in the base. A downward pull upon this arm of the lever started or stopped the second hand, or returned it to zero. This pull was made by the pressure of the foot upon a pedal. One end of this pedal was hinged to a foot stool, and the other end transmitted the downward motion to the arm of the lever by means of an ordinary bird-cage chain and spring. The spring was employed to lengthen the "life" of the stop-watch. When the pressure was released, the lever was restored to a horizontal position by the combined action of the spring in the stem of the watch and a small coil spring that drew the other arm of the lever towards the base.

Six reagents served in this group of experiments. All were graduate students in psychology except one. This one, *V,* was the only woman in the group. She was a junior in college, and had completed an introductory course in psychology. *B*'s purpose in serving as a reagent was primarily to gain first-hand critical knowledge of the methods. If *B*'s reactions had been perceptibly affected by knowledge of the experiment or by any anxiety when the method disclosed its weaknesses, his data would not have been included in the results. The absence of any indication of such influences signifies that the keeping of the observers in ignorance of their time records was a needless precaution. The writer, *B,* was one of the five who were beginning typewriting. *C* was the only subject who knew the arrangement of the keys on the keyboard before beginning the experiments. He had begun the third stage on a similar keyboard, the Oliver, but was quite out of practise. The others were prompted at first by a diagram of the keyboard, which was placed on the screen below the copy. After having located the desired letter on the diagram, there remained the difficulty of striking its key. As it was usually quicker and easier to recall the motor action associated with a letter than to find it, the diagram was used only when necessary.

During the first stage, each series consisted of seven letters of one bank of keys used in mixed order three times. These twenty-one letters were presented in typewritten form, and were separated by spaces into groups of three letters each. This grouping of the letters made the series easier to read. When the reagents became able to locate the keys readily they practised until groups of letters began to become units of reaction and then were initiated into experiments in the second stage. During this second stage of practise the subject matter of the series was a phrase of five words. These phrases were so selected as to present as equal degrees of difficulty as possible. At the beginning of each experimental period a record was made of the reagent's condition for work, and of what he had been doing before the experiment. Then owing to the fact that the mind requires time to adjust itself to an occupation, a rather difficult series was written three times as a warming-up exercise. Following this the series that was practised during the previous period, was tested by three repetitions. Finally the subject practised a new series thirty times. The manner of repeating each of these series was as follows: When the experimenter gave the signal, ''Ready,'' the reagent placed his hands in any position of preparedness on the keyboard that he chose. He refrained from lowering his eyes to the copy, until the experimenter started the watch and at the same time signaled, ''Begin.'' The reagent wrote the series once, and immediately after striking the last key said ''Now''; whereupon the experimenter stopped the watch. A rest of thirty seconds then intervened during which the experimenter recorded the time, his observations, and the introspections of the reagent. The rest after every tenth repetition was lengthened to one minute to give an opportunity for the recording of more detailed introspections. On the completion of thirty repetitions, the experimenter induced the retrospection of the process as a whole by means of questions. An interval was allowed to elapse before the series practised was tested and a new series learned. The lengths of these intervals were 4, 7, 14, 21, 28 and 35 days. One hundred and twenty-four experiments were performed in this group. However not all results could be included in the tables owing to unusual conditions. Besides, reagent *E* left school before the experiments in Tables XVI. and XVII. were completed. As is usual in studies of forgetting, the curve is found in terms of the amount of gain that eventually has been lost through delay. The average time required in writing the series the first three times, minus the time consumed in writing it the last three times during practise, served as the measure of the gain. In like manner, the loss was found by subtracting the average of the three repetitions at the close of practise from the average of the test three given after the interval. Therefore the amount that was forgotten was equal to the loss divided by the gain.

TABLE XIII

First Stage in Typewriting

Seconds Gained through Practise and Lost through Forgetting

Reagents	*M*		*P*		*E*		*B*		*V*	
	Gains	Losses	Gains	Losses	Gains	Losses	Gains	Losses	Gains	Losses
1 day	27.3	3.9	26.3	3.1	18.3	.5	29.6	9.7	39.9	8.7
4 days ...	23.5	6.4	19.0	6.1	24.2	3.5	32.4	18.1	23.1	7.3
7 days ...	8.8	2.4	8.7	4.5	19.8	10.2	27.4	16.2	24.0	13.6
14 days ...	9.5	4.3	27.0	10.9	36.4	24.2	17.2	11.0	61.9	38.3
21 days ...	11.8	7.7	33.0	18.8	18.4	16.7	16.7	12.3	26.6	18.9
28 days ...	7.2	4.5	8.6	5.5	5.9	5.3	39.3	27.7	6.0	4.8
35 days ...	5.7	4.9			21.7	15.3	40.4	39.8		

TABLE XIV

First Stage in Typewriting

Per Cent. Forgotten

Reagents	*M*	*P*	*E*	*B*	*V*	Average
1 day	14.3	11.8	2.7	32.8	21.8	16.7
4 days	27.2	32.1	14.5	55.9	31.6	32.3
7 days	27.3	51.7	51.5	59.1	56.7	49.3
14 days	45.1	40.4	66.2	63.9	61.8	55.5
21 days	65.2	56.9	90.7	73.7	71.1	71.5
28 days	62.5	63.9	89.8	70.5	80.0	73.3
35 days	85.9		70.5	98.5		84.9

The results of practise on the typewriter previous to the stage in which words begin to act as wholes are the subject matter of Tables XIII., XIV., and XV. These tables show that the amount forgotten was, during the first day more than ⅕, by the end of 4 days nearly ⅓, during 7 days ½, and during the entire period, 35 days, more than ¾. However, there was little loss after the 21st day; for ½ of it took place within the first 5 days. Nearly ½ of the loss of the first week had taken place by the close of the first day. As observer

TABLE XV

C's Results

	Gain	Loss	Per Cent. Forgotten
1 day	13.0	2.3	17.7
4 days	16.6	4.1	25.3
7 days	13.1	3.8	29.0
14 days	86.3	38.7	44.8
21 days	12.0	6.3	52.5
28 days	11.5	5.8	50.4
35 days	24.3	13.6	55.9

C had reached the expert stage in typewriting at a previous time; but was out of practise when he began to serve in these experiments, and as the other observers were all beginners, his results were collated in Table XV. His losses were, during the first day less than ⅕, during the first 4 days ¼, during the first 21 days ½, and during the 35 days, ⅗. It is evident that only ⅒ was forgotten during the last two weeks of the period that was studied. *C* wrote as slowly as the others during the early experiments and made as large gains but smaller losses. His general progress, therefore, was much more rapid than that of the beginners until he approached the fastest speed that he had ever attained. Both his gross gains and losses then became small; but the per cent. of his losses throughout the period averaged about ¾ of that of the beginners. The results of the writer, *B,* were allowed to be a part of Tables XIII. and XIV. because they showed no advantages or disadvantages arising from his more intimate knowledge of the purpose and plan of the experiments and of his own time record and errors.

TABLE XVI

Second Stage in Typewriting

Seconds Gained through Practise and Lost through Forgetting

Reagents	*M*		*P*		*B*		*V*	
	Gains	Losses	Gains	Losses	Gains	Losses	Gains	Losses
7 days	19.8	7.9	27.8	5.8	14.9	5.6	16.5	3.8
14 days	9.1	6.2	19.1	11.2	17.2	7.6	7.7	5.9
21 days	11.8	9.9			14.1	10.3	26.6	18.9
28 days					19.6	18.7		

TABLE XVII

Second Stage in Typewriting

Reagents	Per Cent. Forgotten				
	M	*P*	*B*	*V*	Averages
7 days	39.9	20.9	37.2	23.6	30.4
14 days	68.1	58.6	44.2	76.6	61.9
21 days	83.9		73.0	71.1	76.0
28 days			94.5		94.5

TABLE XVIII

SECOND STAGE. *C*'S RESULTS

	Gains	Losses	Per Cent. Forgotten
7 days	19	— 4	—21.1
14 days	11.5	6	52.2
21 days	50.5	12	23.7
28 days	92	—20	—21.7

Tables XVI., XVII., and XVIII. are composed of the results obtained after it had become no longer necessary to think separately of each letter and its corresponding key; and when words began to serve as units in this period the progress in learning was slower than in the previous period, and the rate of forgetting was even slower. The amount lost was, during the first 7 days almost ⅓, during the first 14 days ⅔, and during the first 21 days more than ¾. Nearly all that had been learned was forgotten by the end of 28 days. As shown in Table XVIII., by the time the beginners were in this stage of typewriting, *C* was no longer making definite losses within intervals as short as those which we have been studying.

TABLE XIX

SECOND STAGE. FEW REPETITIONS IN PRACTISE

Intervals	Gross Gain	Gross Loss	Per Cent. Forgotten
5 minutes	141	25	18.4
20 minutes	140	48	35.3
60 minutes	141	77	54.6

In Table XIX. are presented the results of experiments like those in Tables XVI. to XVIII. except that the sentences were practised twenty times instead of thirty. *B* was the only subject. Four sentences were tested after five minutes and showed a loss of one fifth of what had been gained. Four were allowed an interval of twenty minutes with a loss of one third. Finally four sentences were tested sixty minutes after the end of practise, and resulted in the forgetting of two thirds of what had been learned. Therefore Table XIX. shows greater losses during the first 20 minutes and almost as great losses during 60 minutes as took place according to Table XVII. in the first 7 days and the first 14 days. It is clear then that if subject matter of this kind is well memorized the losses are much slower than when the association links are not so thoroughly established; but that the last part of the curve rises more slowly with twenty repetitions than with thirty repetitions.

The time of writing a series was often decreased at the expense of accuracy. On the other hand, in the effort to avoid all inaccuracies the subjects purposely diminished the speed in parts of the series where mistakes could be avoided without especial care. In these cases the least suggestion of carefulness, such as was brought about by the discovery of an error in previous work, resulted in slower time on the next trial. In other words, when attention was focused on accuracy, the time was lengthened and rendered much more variable than when exactness was subordinated to speed. It seems expedient, for these reasons, for the reagents to exert themselves chiefly for rapidity, and at the same time, to endeavor to give accuracy as close a second place in consciousness as possible. In practise every error of order was accompanied, on an average, by 7 errors of omission and 9 errors of insertion. Practise reduced these omissions 49 per cent., the insertions 73 per cent., and the mistakes of order 50 per cent. during the first stage of practise. The average amount of this reduction of errors that reappeared owing to delays in recall was in the cases of omissions 26.3 per cent., of insertions 2 per cent., and of errors of order 88 per cent. It is evident that although the insertions were more numerous than the two other types of error, their number was reduced more rapidly by practise and was much more slowly increased by subsequent delay. Practise had almost equal effect upon omissions and cases of wrong order; but forgetting increased errors of order more than three times as fast as errors of omission. Hence, errors of order, although much less frequent than the other two types were the most difficult to get rid of by means of practise. This statement is also supported by the fact that *C*, who was in the third stage of typewriting, made relatively more mistakes of order than were made by other subjects.

The method which has been employed in the preceding experiments can be called a method of reproduction, as contrasted with the saving or relearning method of Ebbinghaus. As it has been employed in this chapter, the method of reproduction consists in first determining the gain in a certain associative performance due to a specified amount of practise, and then determining the loss of proficiency that results from a given interval of no practise. The loss divided by the preceding gain shows what proportion of the gain due to practise has been lost in a period of no practise, and therefore may properly be regarded as a measure of the amount forgotten. The results of this method are in general agreement with the familiar results of the saving method, but seem to be subject to more variation. It was now desired to institute a direct comparison between the two methods, with a view to ascertaining which gave the more regular and reliable results.

With this in view, an experiment was conducted in which both the method of reproduction, as above described, and the method of relearning, were employed together. The performance studied was, as before, typewriting; and, as before, the experiment began with a specified amount of practise, which was followed by an interval of no practise. After this interval, still as before, a test was conducted to determine how much of the gain through practise had been lost in the interval; but now this test was followed by a new period of practise, continued until the former high point of practise was again reached. The time required to relearn the performance and regain the former proficiency could be compared with the time required to reach this proficiency in the first period of practise.

The subject matter of each experiment consisted of a couplet from Longfellow's "Evangeline." As great care as possible was exercised in the selection of couplets that were equally easy to write on the typewriter. The subjects were two normal school students. Both were men whose age and degree of maturity was about the same as that of college juniors. As previous experiments have not given evidence in favor of keeping the observer ignorant of his errors and his time, and as the group of experiments was necessarily too brief for much to be accomplished in the touch method of typewriting, the writing and the keys were allowed to be visible, and the observer started and stopped the watch and reported the time. Nevertheless, all this work was done under close supervision. Before practise and before the final test, the alphabet was written twice as a warming-up exercise. The couplet was practised thirty minutes.

TABLE XX

METHOD OF REPRODUCTION

Seven Days Interval

Experiment		First	Last	1st Test	Gain	Per Cent. Gain	Loss	Per Cent. Loss		
H	III.	3.08	2.8	4.67	1.00	32.5	2.59	259.00		
	IV.	3.00	1.75	3.00	1.25	41.7	1.25	100.00	*H*'s Av. .	140.0
	V.	3.92	2.00	3.17	1.92	38.40	1.17	60.9	*G*'s Av. .	63.4
G	I.	16.00	7.00	13.50	9.00	56.2	6.50	72.2	Total Av.	101.7
	V.	2.91	1.87	2.83	1.05	36.1	0.96	91.4	A.D.	51.6
	VI.	13.50	6.00	8.00	7.50	55.6	2.00	26.7	P.E.	17.3

An interval of one half minute followed each repetition as a rest, and as an opportunity to record the time and to report introspections. Each series was relearned to its former degree of proficiency either seven days or fourteen days after it had been first learned. The time required to write the couplet the first time and the last time in practise and also the first time in the relearning of it were used as the means of determining the gain and the loss, by the method of reproduction. These results are found in Tables XX. and XXI.

TABLE XXI

METHOD OF REPRODUCTION

Fourteen Days Interval

Experiment		First	Last	1st Test	Gain	Per Cent. Gain	Loss	Per Cent. Loss		
H	I.	20.00	8.00	10.08	12.00	60.0	2.08	17.3	Total Av.	31.4
G	IV.	4.00	2.00	2.91	2.00	50.0	0.91	45.5	A.D.	14.1
									P.E.	8.5

The number of repetitions in learning and in relearning were the data of the relearning method, and were used in constructing Tables XXII. and XXIII.

TABLE XXII

METHOD OF RELEARNING

Seven Days Interval

Experiment		Repetitions in Learning	Repetitions in Relearning	Per Cent. Necessary in Relearning		
H	III.	13	4	30.8		
	IV.	13	5	38.5	*H*'s Av. ..	39.8
	V.	4	2	50.0	*G*'s Av. ..	44.8
G	I.	4	2	50.0	Total Av.	42.3
	V.	9	4	44.4	A.D.	5.8
	VI.	5	2	40.0	P.E.	2.0

TABLE XXIII

METHOD OF RELEARNING

Fourteen Days Interval

Eqperiment		Repetitions in Learning	Repetitions in Relearning	Per Cent Necessary in Relearning		
H	I.	3	2	66.7	Av.	66.7
G	IV.	6	4	66.7	A.D.	0

The tables show that according to the method of relearning the losses of the two reagents are almost equal. The average deviations and probable errors in Tables XXII. and XXIII. are such as would indicate relative freedom from erroneous measures. The average losses of both reagents are according to the method of reproduction greater in 7 days than in 14 days. Besides, *H*'s average per cent. in the 7 days according to the table of reproduction is 2.3 times *G*'s average; but according to the table of relearning the two averages are almost equal. In the reproduction table for 14 days, *G*'s average per cent. is nearly three times that of *H*. But in the corresponding table of relearning the per cents lost are exactly equal. In Tables XX. and XXI. the average deviations are about half as large as their respective averages and the probable error in Table XX. is ¼ as great as its average. On the other hand in Table XXII. the average is more than seven times as large as the average deviation and more than ten times as large as the probable error, and in Table XXIII. the average deviation is zero. There is no doubt, therefore, of the superiority of the results in the tables of measurements by relearning to the tables of measurements by reproduction. However, differences between reproduction and relearning are not much greater in these tables than might be expected, in view of the fact that only one measure, instead of the average of three measures, as elsewhere in the chapter, was the basis of the calculations of gain and of loss in reproduction. The method of reproduction is subject to large chance errors in the single measurement.

The results of this chapter may be summarized as follows: The curve of forgetting has been determined for the complex associative performance of typewriting a specified list of letters or of words. This curve has been found to have the same general character as that familiar from the work of Ebbinghaus on much simpler performances; the similarity consists in a more rapid rate of forgetting soon after cessation of the learning than later. But the actual rate of forgetting has been found to depend very largely on the amount of learning preceding the period of forgetting. When the amount of learning is small, the forgetting is at first rapid, but when the amount of learning is greater the forgetting starts at a much slower pace than is shown in the Ebbinghaus curve. In the latter case, the rate of forgetting is not excessively rapid at first, and, though it decreases, it decreases more slowly than in the usual curve.

CHAPTER VI

Discussion of Results and General Conclusions

It will be remembered that this investigation is (1) a further study of the curve of forgetting as to its form and as to the rate of loss in association strength after practise has ceased, and (2) a search for reasons for the dissimilarities in the curves already found.

The curves that have been obtained by others in the more extensive investigations of forgetting are shown in dotted lines in Fig. 3. The curve of Ebbinghaus for nonsense syllables rises with great rapidity during the first day, undergoes a marked decline in rate during the following five days, and ascends slowly during the remaining 25 days. Radossawljewitsch's curve for the same kind of material makes its rapid ascent within the first two days. The change to slower rates of loss is somewhat more gradual than that of Ebbinghaus; but the latter portion of the curve shows a more rapid rate of forgetting than was found by Ebbinghaus. My curves for meaningless subject matter indicate that association strength decreases remarkably during the first day. Almost all of the loss that is shown by the curve which was determined by the method of selection had taken place by the end of the first week. The curve found by the method of reproduction rises very little after the second week. Radossawljewitsch's curve for the forgetting of matter with meaning does not differ greatly from his curve for meaningless subject matter except that it is much more irregular and therefore more difficult to interpret. His curve for material with meaning is slower than his other curve until the end of the third day, and indeed it indicates less decline in the ability to learn after an interval of a month. My curves for typewriting show a great loss of association strength during the first week and a gradual falling off in the amounts forgotten during the remainder of the month. This diminution in the amount forgotten is not so evident in the curve of the second stage as in that of the first stage of typewriting. Observer *C*, who had once attained considerable ability in typewriting but was out of practise when he began to serve as subject, produced a curve that rises rather rapidly during the first day, at a gradually decreasing rate to twenty-one days, and slowly thereafter. In his second stage his curve, if it were delineated, would be so irregular that it would give no evidence either of gain or of loss. It is evi-

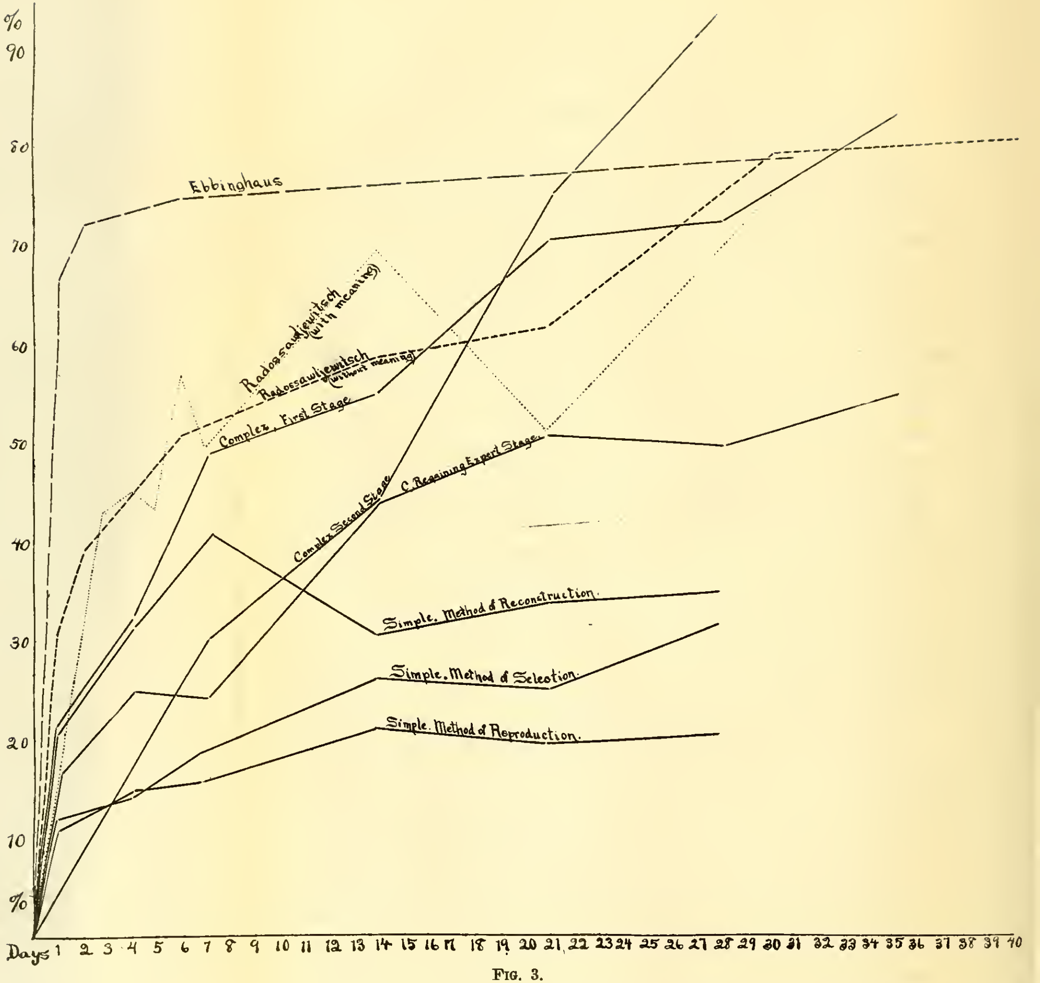
%
90
80
70
60
50
40
30
20
10
%
Days 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
Ebbinghaus
Radossawljewitsch (with meaning)
Radossawljewitsch (without meaning)
Complex, First Stage
Complex Second Stage
C. Regaining Expert Stage.
Simple. Method of Reconstruction.
Simple. Method of Selection.
Simple. Method of Reproduction.

FIG. 3.

dent that to a considerable extent the form of the curve of forgetting resembles that of the curve of learning. However, the forgetting curve for nonsense syllables has a more abrupt change from its rapid rise than is found in memory curves. This short turn in the curve is probably due to the primary dependence of the memory of meaningless subject matter upon the innate retentiveness of the brain centers that are immediately involved; and, owing to the poverty of meaning, it is dependent only in a secondary way upon the few indefinite interactions that can be set up with other centers. These are such trivial relations that they rapidly decline, and after a remarkably short period, the slowly fading impressions of the other sort are all that remain.

The curve of forgetting may be studied (1) as to its general form; and (2) as to the absolute rate of forgetting. Suppose the general form of the curve to be constant, and to have the roughly "logarithmic" character signalized by Ebbinghaus—a form indicating that the rate of forgetting is most rapid at first and becomes slower and slower—and suppose further that the absolute rate of forgetting varies with conditions. Then it is clear that a rapid absolute rate of forgetting would make the rise of the curve very steep at first, and would lead to an apparently abrupt transition from this rapid forgetting to the slower forgetting that ensues. On the other hand, a slow absolute rate of forgetting would cause the initial rise of the curve to be less steep and the transition from this to the ensuing portion of the curve less abrupt. But such changes leave the general character of the curve unchanged; they affect only a certain "parameter" of the curve, and could be obliterated, in the graphic representation of the facts, by simply altering the horizontal scale of the graph, making this scale proportional to the absolute rate of forgetting. Reducing the horizontal scale would change a slowly rising curve, with a gradual transition from the initial to the later phase, into a rapidly rising curve with an abrupt transition from the initial to the later phase.

Inspection of the various curves in Fig. 3 shows that the differences between them are approximately of the sort just described. They differ in the absolute rate of forgetting, but not in the general character of the curve. All belong approximately to the logarithmic type. The results of the present study have not brought to light any curve of forgetting of a definitely different type. Such divergences as have appeared are probably to be considered as accidental variations. Much the same can be said of the divergences from the logarithmic type of curve which are emphasized by Radossawljewitsch[9] in particular the apparent recovery between 8 and 24 hours. He found that less was forgotten in 24 hours than in 8 hours—or, at least, that the saving in relearning was greater after 24 than after 8 hours. This may reasonably be attributed to the fact that the 8-hour interval brought the relearning into an unfavorable time of the day, while the 24-hour interval allowed sleep to intervene and brought the time of relearning back to the original hour of the day, with all conditions, external and internal, most nearly identical with those of the first learning.

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[9] *Op. cit.*

In brief, a survey of previous results as well as of the results of the present study gives no warrant for altering the general character of the Ebbinghaus curve of forgetting, nor for introducing any other general type of curve alongside of that.

But as regards the absolute rate of forgetting, the literature of the question, as well as the experiments herein reported, gives abundant evidence that this is a variable quantity. The rate of forgetting depends on the following factors:

1. It depends on the degree to which the material has been learned before the commencement of the period of forgetting. This was already indicated in the original experiments of Ebbinghaus, since he found that any study of the material beyond the point necessary for one correct reproduction made it easier to relearn the material later, or, in other words, diminish the degree of forgetting after a given interval. The rate of forgetting was slower when ''overlearning'' had occurred than when the study had been barely sufficient to reach the standard of one correct recitation. It is probable that the slow rate of forgetting found by Radossawljewitsch was the result of his requiring such an amount of study as would make possible *two* correct recitations in succession, instead of only one; for this author found that the amount of study needed for two correct recitations was often considerably more than that required for one correct recitation. It is likely that others of the discrepant results in the literature, in regard to the rate of forgetting, depend on this matter of overlearning.

In one of the experiments of Chapter V., a direct comparison is instituted between the rates of forgetting when preceded by different amounts of learning. When the subject of this experiment practised a list of words on the typewriter 30 times, he forgot, after 7 days 37.2 per cent., after 14 days 44.2 per cent., after 21 days 73.0 per cent., after 28 days 94.5 per cent. But when the initial learning was limited to 20 repetitions, he forgot 18.4 per cent. in 5 minutes, 35.3 per cent. in 20 minutes, and 54.6 per cent. in 60 minutes. The curves of forgetting in the two cases have the same general form, but the absolute rate of forgetting is much more rapid after the smaller amount of practise.

A method developed in this same chapter, though not employed specifically for the problem now under discussion, seems specially adapted to its study, in that it permits of a measure of the amount of "overlearning" in terms of proficiency acquired instead of simply in terms of the number of repetitions. The proficiency being measured by the speed of performance, the subject practises a given performance till he reaches a certain degree of proficiency, and then, after an interval of forgetting, practises again, or relearns, till he reaches the same degree of proficiency as before. In different experiments, the degree of proficiency to be attained can be varied, and the curve of forgetting thus traced from different starting points. Though the test has not been made with exactly this method, the probability is, from the results at hand by a slightly different method, that the curves of forgetting would have the same general form from whatever level of proficiency they start, but that the rate of forgetting would become slower and slower as the initial level of proficiency was raised. Book,[10] it will be recalled, after attaining a considerable degree of proficiency in the use of the typewriter, interrupted practise for a year, and then found but a few minutes fresh practise needed to reach his former level. The saving method of computation here indicates a forgetting of less than 1 per cent. in a year.

2. The rate of forgetting probably depends on the distribution or concentration of the process of learning. This is indicated by results of Ebbinghaus, Jost and others. When the practise leading to a certain degree of proficiency has been distributed over several days, the rate of forgetting is slower than when the practise has been concentrated in time, though the proficiency reached be the same in the two cases.

3. The rate of forgetting varies with the performance or material learned. It is slower for meaningful than for nonsense material. Aside from meaning in the intellectual sense, it is probable that other differences in the kind of performance affect the rate of forgetting. Thus skill in throwing at a target (Chapter III. above), though slowly acquired, was slowly forgotten—almost too slowly to furnish the basis for a study of the curve of forgetting. Again, in the typewriting experiments (Chapter V.), though the number of repetitions constituting the first learning of a performance was not greater than is often necessary in learning a list of nonsense syl-

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[10] "The Psychology of Skill," p. 76.

lables, yet the rate of forgetting of the typewriting act was noticeably slow. Such performances as typewriting or throwing at a target differ from the recitation of lists of nonsense syllables in possessing a sort of motor meaning or significance. They do not appear, introspectively, as meaningless performances, but seem to accomplish something, and it is possible that this practical meaning is like meaning of the more intellectual sort in favoring the retention of what has been learned.

4. The rate of forgetting varies according to the method by which it is measured. Different rates are to be expected according as retention is measured by power of reproduction or by time of relearning. The results in Chapter V. would indicate, though not very reliably, that the rate of forgetting is more rapid when measured in terms of reproduction than in terms of relearning. Reproduction seems certainly the more direct test of the present strength of old associations, and relearning measures, rather the effect of fresh study upon the old associations; but the method of reproduction is the more subject to accidental error.

The method of reproduction gives different results according as time or accuracy is the criterion; and if accuracy is the criterion, the rate of forgetting comes out differently according to the kind of errors that are counted. If omissions are counted, forgetting appears to occur more rapidly than when insertions are counted. Insertions, the easiest errors to eliminate through practise, are the slowest to reappear during the intermission of practise. Errors of order are rather difficult to eliminate, and quickly reappear after intermission of practise. It is clear that these divergences of result, according to the unit of measurement, are not simply indications of unreliability in the methods, but are evidences that any statement of the rate of forgetting, without specification of the kind of loss, have little if any meaning. Measurements in terms of time have usually been treated as if free from such limitations; but this is not justified unless there is constancy in all these other respects.

Further, the rate of forgetting comes out differently according to the manner of recall adopted in the test for power of reproduction (Chapter IV.). This is by reason of the fact that one form of recall makes use of one kind of elements of the past experience, and another form of recall another kind of elements. When the method of reconstruction is employed, the subject can neglect all phases of the past experience except the original order of the members of the series. The method of selection or recognition tests only the ability to recognize the former experiences when they are again presented. The reproduction of the whole series in proper order would seem to make the greatest demands upon the associations and to be the most complete method. But the curve of forgetting can properly be measured by any of these methods, and the curve, or at least the rate of forgetting, differs with the method. Order is forgotten with great rapidity at first and much less rapidly later. The ability to recognize is lost rather gradually. The ability to reproduce is lost rather rapidly at first, and the transition to the period of slow forgetting is sometimes gradual and sometimes abrupt.

5. The rate of forgetting shows individual differences in retentiveness. The present study has not revealed any sex difference in this respect. It appears, from the work of earlier investigators, that the rate of forgetting depends on age. Probably, the other factors concerned in forgetting being equal, young children forget more rapidly than adults.

ACKNOWLEDGMENTS

The readers of this paper whose teachers have manifested an interest, not only in the solution of the problems of their studies, but also in their problems of life, can most fully appreciate my gratitude towards those who have instructed me by means of this research, and have given me encouragement when I needed it most. Professor James R. Angell first launched me in this investigation, and Professor John Broadus Watson rendered helpful advice. Professors J. McKeen Cattell, E. L. Thorndike, and R. S. Woodworth generously spent many hours with me in interviews that were replete with valuable suggestions. I wish to acknowledge also my obligations to the large number of persons who served as reagents.

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	Taryn Villano
	6th Gainsborough St
JAN 0 2 1990	Boston
	045-74-2745

PSYCH
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Bean, Charles Homer, 1870-
The curve of forgetting, by C. H. Bean. New York, The Science Press [1912]
iii, 45, [1] p. incl. tables, diagrs. (1 fold.) 25 cm. (Archives of psychology, ed. by R. S. Woodworth. no. 21)

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